



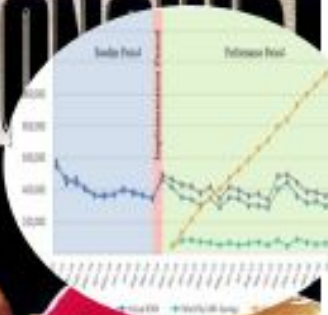
M&V Insights from the Field: Whole Building and Bottom Up

Chris Smith and Kevin Campbell

October 24, 2016

LIVE! THE WORLD LIGHTWEIGHT

Product	Weight	Price
4701	1000	\$100
4702	1000	\$100
4703	1000	\$100
4704	1000	\$100
4705	1000	\$100
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4796	1000	\$100
4797	1000	\$100
4798	1000	\$100
4799	1000	\$100
4800	1000	\$100



Yearling	Sex	Color	Age	Weight (lb)	Height (in)	Withers (in)	Heart Girth (in)	Body Length (in)	Throat Girth (in)	Fore Limb (in)	Mid Limb (in)	Heel to Toe (in)	Canter (in)	Gallop (in)
101	Male	Bay	2	1100	58	48	70	60	50	24	22	30	28	32
102	Female	Bay	2	1050	56	46	68	58	48	22	20	28	26	30
103	Male	Bay	2	1150	60	50	72	62	52	26	24	32	30	34
104	Female	Bay	2	1000	54	44	66	56	46	20	18	26	24	28

WHICH CHAMPION IS THE BEST?

Bottom Up
M&V

Whole
Building M&V

SAT., APRIL 20 **HBO** AT 9:30^{PM}/6:30^{PM}

[illegible]

LIVE! THE WORLD LIGHTWEIGHT

WHICH CHAMPION IS THE BEST?

Bottom Up M&V | **Whole Building M&V**

SAT., APRIL 20 **HBO AT 9:30^{PM}/6:30^{PM}**

Subtitles will be in English. HBO, HOME ENTERTAINMENT

Financial Metrics Table:

Company	Market Cap	Revenue	Profit	EPS	P/E Ratio	Dividend	Yield
Company A	10.5B	1.2B	0.1B	1.50	15.0	0.50	3.3%
Company B	8.2B	0.9B	0.08B	1.20	16.7	0.40	2.9%
Company C	6.1B	0.7B	0.06B	0.90	18.9	0.30	2.5%
Company D	4.8B	0.5B	0.04B	0.70	21.4	0.20	2.1%
Company E	3.5B	0.4B	0.03B	0.50	23.8	0.15	1.8%

Line Graph Data:

Index Point	Performance Point
10000	10000
10500	10500
11000	11000
11500	11500
12000	12000
12500	12500
13000	13000
13500	13500
14000	14000
14500	14500
15000	15000
15500	15500
16000	16000
16500	16500
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17500	17500
18000	18000
18500	18500
19000	19000
19500	19500
20000	20000

The Problem

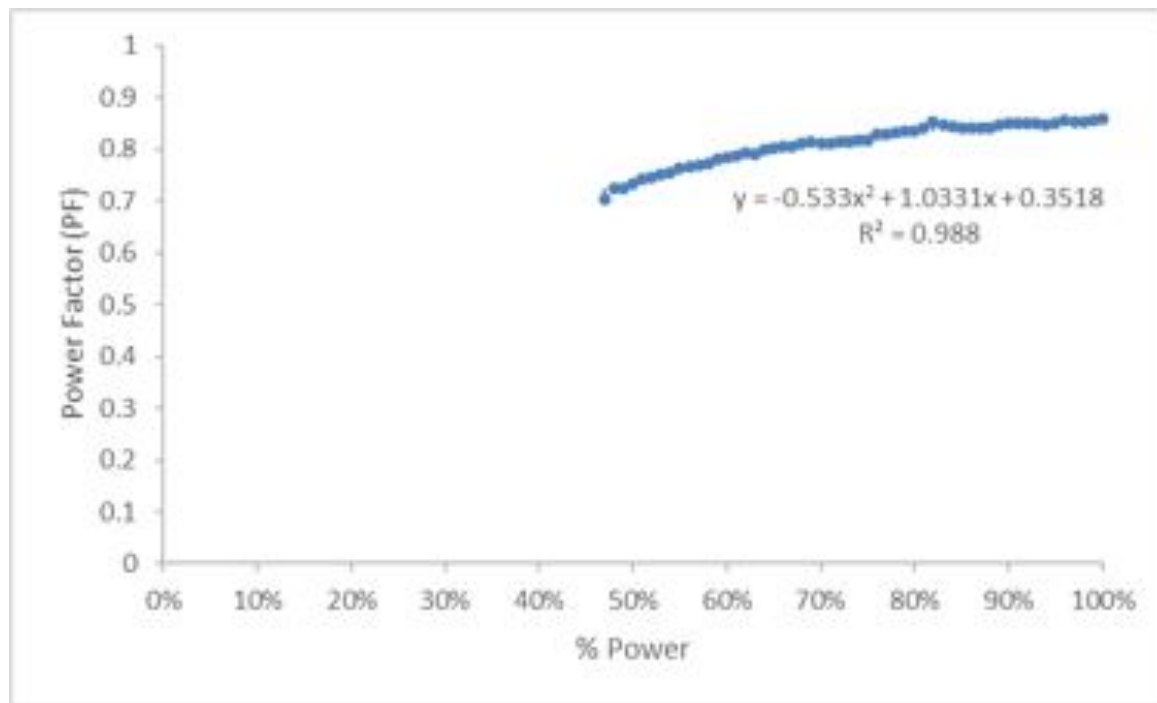
- What would have happened absent the intervention?
- A simple case: LED street lighting retrofit



Simple Upgrade – Frozen ERV on Single Zone HVAC System



- Bottom up M&V – Equipment and methods matter



- Frozen ERV



- Disconnected Pressure Sensor



Complex Upgrade – RCx of Large Commercial Building

- Disabled/Broken Economizers



- Behavior Based Changes



- Thermostat in the Sun

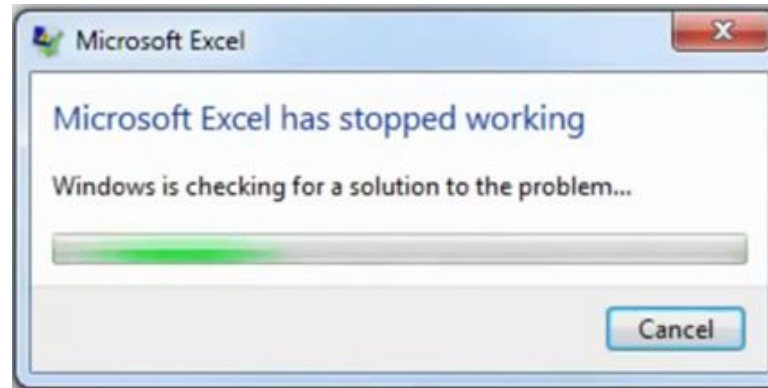


- Steam Venting Into Tower



- Requires unique skillset
 - Energy engineering and statistics
 - Resources and best practices are more accessible
- Models should not be developed in a vacuum
 - Knowledge of energy systems at the site
 - Understanding of other operational changes at the site
 - Knowledge of other energy projects at the site

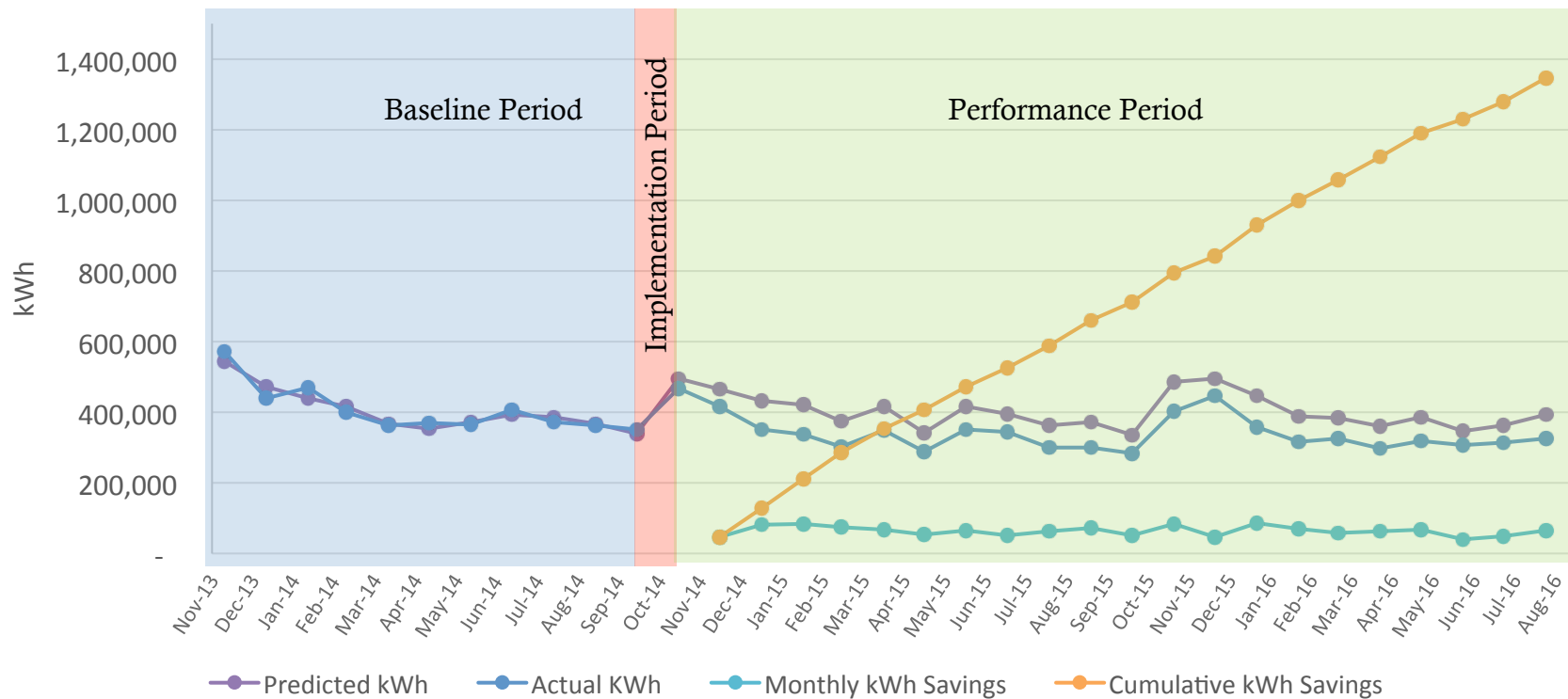
- Multitude of independent variable combinations
 - Industrial facilities
 - Commercial buildings
- The tool should match the application



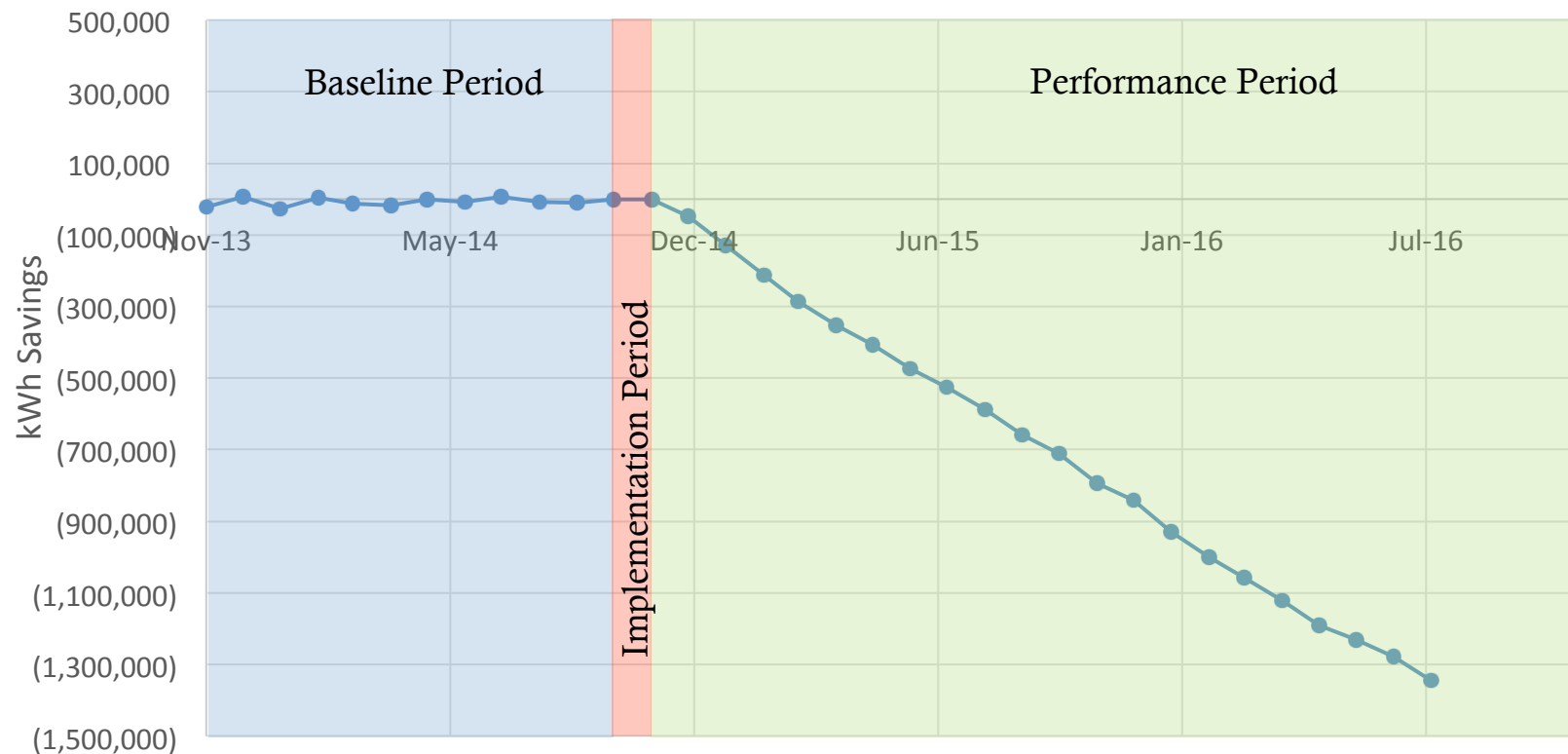


- Energy Star Building
- Has implemented a number of capital projects, even LED lighting
- All electric, water cooled DX, VAV airside systems
- Through building tuning, saved 16% of energy use (794,386 kWh)
- Energy Star score went from 80 to 91
- Project included minimal capital equipment
- Savings have been measured and verified at the meter
- Building manager billed the expense to the triple net – means the tenants paid for it!

1000 Broadway Energy Performance



1000 Broadway Cumulative Sum of Savings (CUSUM)



1000 Broadway Energy Model – It's not that complicated!

- Regression model that uses independent variables to quantify savings statistically
- Interval data was not available, so model intervals are monthly
- Independent Variables
 - Cooling Degree Days
 - Heating Degree Days
 - Days in billing cycle
 - Occupancy was tracked, but was highly stable (full), so not used
- kWh Savings = Predicted kWh – Actual kWh

Modeling Stats - Transparency is Key!

<i>Regression Statistics</i>	
Multiple R	0.9502337
R Square	0.9029441
Adjusted R Square	0.8665481
Standard Error	23557.039
Observations	12

ANOVA

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	41301917881	1.38E+10	24.8089	0.000209711
Residual	8	4439472519	5.55E+08		
Total	11	45741390400			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	90262.869	163159.4102	0.553219	0.595231	-285983.406	466509.1433	-285983.4058	466509.1433
X Variable 1	6143.1231	5609.072805	1.095212	0.305298	-6791.422	19077.66817	-6791.421996	19077.66817
X Variable 2	276.25052	41.38871851	6.674537	0.000157	180.8079617	371.6930738	180.8079617	371.6930738
X Variable 3	505.5455	150.87427	3.350773	0.010069	157.6288071	853.4621879	157.6288071	853.4621879

1000 Broadway – Try calculating this at a Measure Level!

- Reduce scheduled occupied times (including exhaust fans)
 - Exhaust fans run 4:00AM-7:00PM Mon-Fri, 8:00AM-Noon Sat - Should adjust schedule to match A/E/R.
 - JAGS run 6:00AM-7:00PM Mon-Fri, 8:00AM-Noon Sat - Can we make this 7AM-5PM? They actually go into occupied mode at 6:00, but with smart stop, they're coming on at 4:00 at least in this colder weather.
 - Can we shorten the lighting schedule?
- Enable morning warmup
 - Command DA Dampers fully closed during morning warmup if DAT<50
- SAT reset
- SP reset
- Fix broken economizers - Suspect economizers include:
 - AC9 - Seems to have very high minimum OA
 - AC10 - Compressor runs in cold weather
 - AC18 - Compressor runs in cold weather
 - AC21 - Compressor runs in cold weather
 - AC23 - Compressor runs in cold weather
- Fix broken VAV dampers
 - VAV 0825 Zone 25
 - VAV 1024 Zone 46
 - VAV 1116 Zone 15
 - VAV 1302 Zone 32
 - VAV 1326 Zone 30
 - VAV 1514 Zone 34
 - VAV 1628 Zone 17
 - VAV 2020 Zone 48
- Is it 19 zone 23 temperature sensor working right? We're cooling it heavily and it says it's 77.
- Reduce Lobby & Theater OA
- Optimize CW Loop
 - Isolate the cooling tower bypass on the primary condenser water loop.
 - Reduce primary flow through VR - Do this until we get a similar DT on each side of the heat exchanger. We could also just measure flow on each side and balance primary flow to match secondary. We should leave the primary a little more than the secondary for when the lobby & theater units need cooling.
 - Program CW pumps to sequence up and down. I think there's plenty of time when we only need one of these.
 - Reduce primary CW DP setpoint from 17 PSI to 777?
 - Program the secondary pumps to lead with the good one and bring the other one on once a week for an hour to exercise it. Also make sure it's programmed so that if the lead fails, the other comes on as a backup.
- Look to Reduce Lighting Schedule - RR and rail lights run 6AM-10:00PM and from midnight-2AM
- AC 18 economizer linkage needs to be connected to the actuator.
- What controls BR exhaust fans? They were running at 1:00 PM on Saturday
- What's EF-17? It runs every day from 7AM-7PM.

We should do a lighting sweep at 8:00 PM then bring the hallway lights back on.

They don't clean Fri & we can shut lighting off at

VAV Name:	VAV-1828 Zone 39	VAV-1
Active Mode:	Occupied	Parallel Fan, with Heat
Present Value:	Occupied	
Space Temperature:	72 Deg	
Unoccupied Cooling Setpoint:	65 Deg	Active Cooling Setpoint: 74 Deg
Occupied Cooling Setpoint:	74 Deg	Active Heating Setpoint: 72 Deg
Unoccupied Heating Setpoint:	72 Deg	Heat Active: Yes
Occupied Heating Setpoint:	65 Deg	Parallel Fan Output: On



Air Valve Position:	20-50 %
Air Valve Flow:	100 Cfm
Air Valve Control Action:	Cooling

More Details

- I reprogrammed the min cfm to 60.

- why does the air valve not close more?

- why does the air valve stay cooling mode, yet fan & heat are on?

Economizers	SP	Actual
-AC9	51	67
-AC10		
-AC11		

up to AC 18
AC 12 → 10%
AC 13 → 10%

	SP	Actual
AC 11	67	57
AC 13	67	51
AC 14	67	64
AC 15	67	62
AC 18	67	53
AC 20	116	60
AC 21	67	61
AC 22	67	53
AC 23	67	54

AC 16 working
is AC 12 working?

62 → still low
53 → linkage is disconnected from actuator

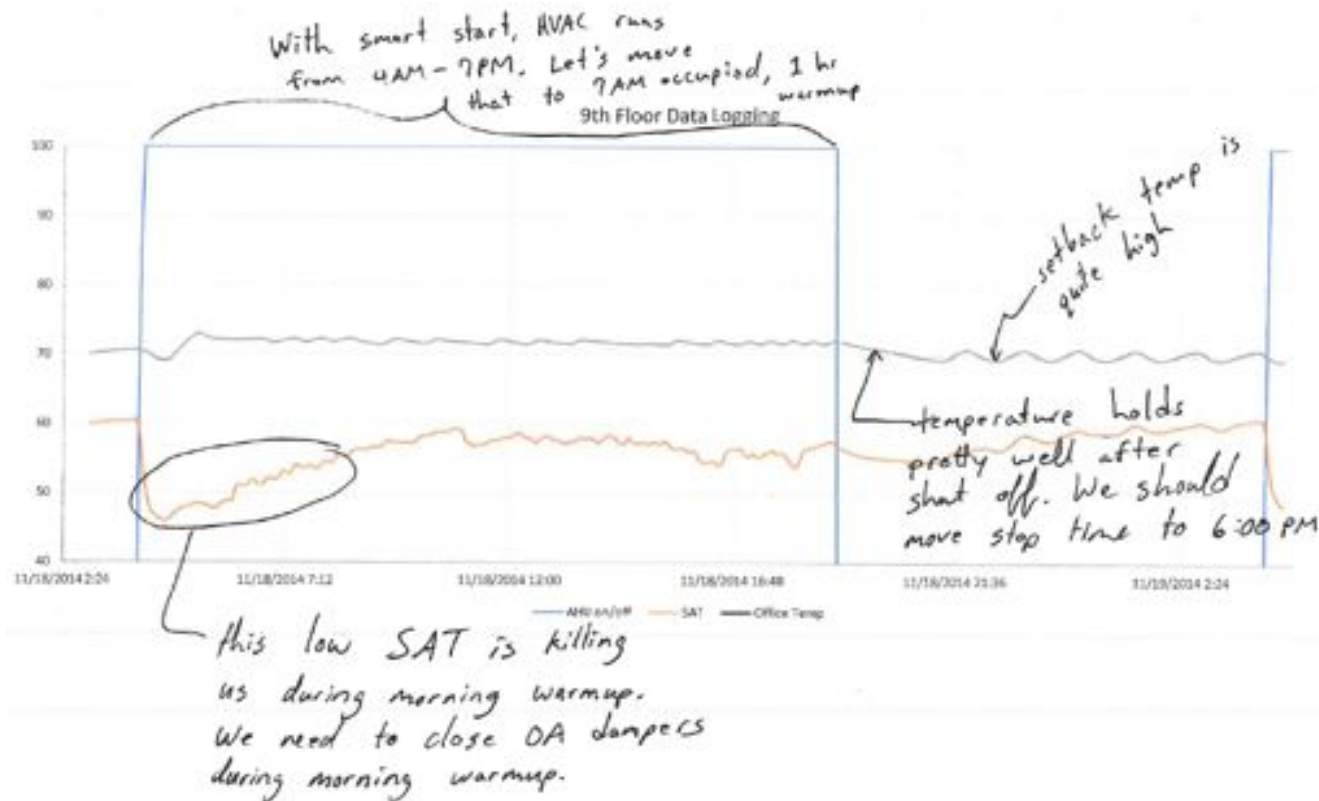
AC 22 @ 10%

Bathroom exhaust fans are on sat at 1:00 what controls them?

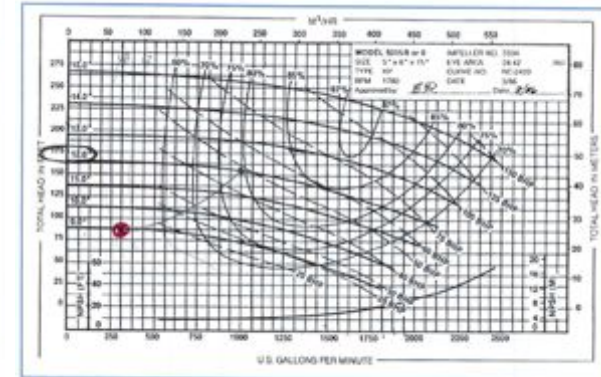
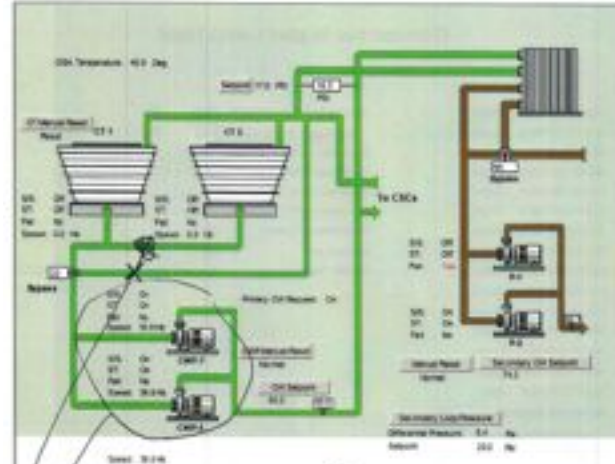
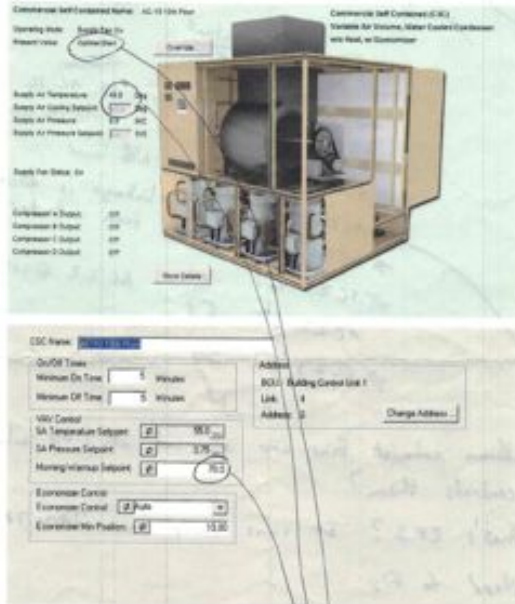
What's EF3? It runs every day 7AM-7PM

Need to fix

1000 Broadway – Try calculating this at a Measure Level!



1000 Broadway – Try calculating this at a Measure Level!



Conditions of Service				Motor Data	
Flow	Temp	Suct. Press.	HP	Voltage	Eff.
LDH	S.G.	Dis. Press.	RPM	1750	55 F.
Fluid	Visc.	Diff. Press.	End.	Hz	

GPM	Temp	EFF	BHP
325	80°	45%	21.4
500	100°	52%	21.8
750	125°	71%	31.7
1,000	155°	80%	48.1

It's in optimal start mode & programmed for a morning warmup temp of 70. Why ~~is~~ the SAT 55? This is making it hard to warm up the building.

Need to sequence these. One should suffice most of the time.

- In considering whole building M&V, we should be honest about our current methods
- Measure level analysis:
 - Requires skill not always possessed by those conducting the analysis
 - We consider evaluation results as absolute – they're prone to the same uncertainty as ex-ante
 - Is really tough for RCx measures or “building tuning”
- Whole building analysis:
 - Also contains uncertainty, but it can be better quantified
 - Is more transparent and easily reviewed
 - Is more efficient for RCx measures
 - Supports a more transactive approach to energy efficiency



Thank You

Chris Smith, PE, CEM - Chris@Energy350.com
Kevin Campbell, PE - KCampbell@Energy350.com

